Linear Ordered Attribute Grammars without fake dependency selection

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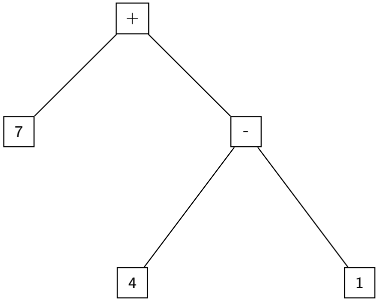
Evaluating Expressions



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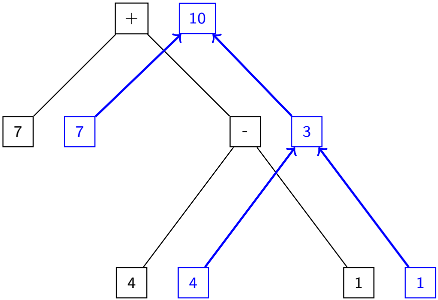

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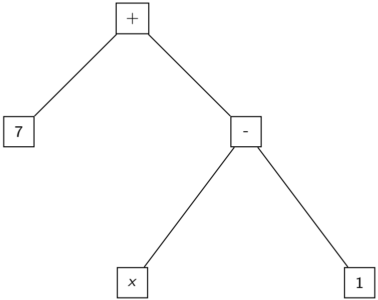

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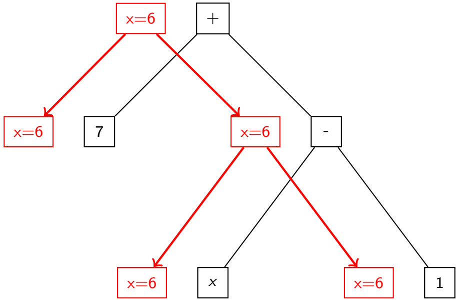

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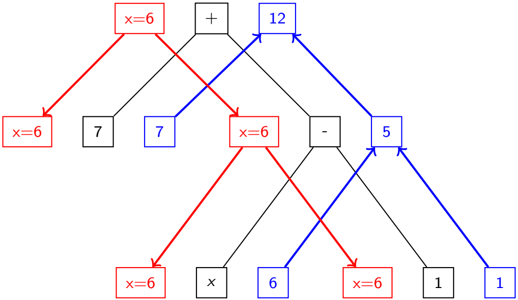
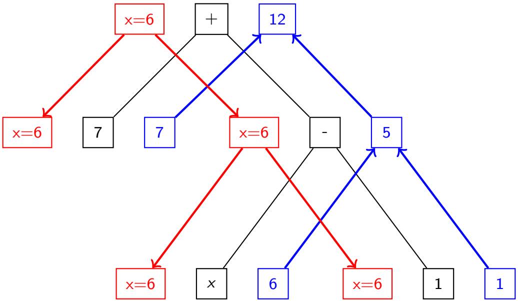


Evaluating Expressions using Attribute Grammars

- Attribute Grammars extend trees with attributes.
- Every node N represents one or more functions, that:
  - Receive a subset of the inherited attributes of N.
  - Produce a subset of the synthesized attributes of N.
- Attribute Grammars form a DSL for tree-based computations.



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Scheduling Multiple Computations

- Easily define multiple computations on the same tree.
- Leave worrying about the evaluation order to some compiler:
  - Host compiler: generating catamorphisms.
  - AG compiler: finding a static evaluation order.

Scheduling Multiple Computations

- To find a static evaluation order, we need to:
  - Find an interface for every nonterminal.
  - Show how every production implements it.
- An AG for which this is possible is linear ordered (LOAG).
- Decision problem:
  "Is there an assignment $i \to s$ or $s \to i$, for every pair (i, s) of every nonterminal X with $i \in inh(X)$ and $s \in syn(X)$, such that there are no dependency cycles?"
- Membership decision is NP-Hard.

Linear Ordered AGs

- Largest class that allows static evaluation schedules.
- Assumed to generate efficient code.
- Only algorithms for subclasses exist.
- Paper describes an algorithm to schedule LOAGs:
  - Exponential in theory, efficient in practice.
  - Compiles the UHC without assistance from the programmer.

Scheduling the UHC

- UHC is partly generated from of a large number of AGs.
- The "main AG" is very large indeed:
  - 30 nonterminals
  - 134 productions
  - 1332 attributes (44.4 per nonterminal!)
  - 9766 dependencies
- The main AG is written as a *linear ordered* AG.
- Kastens Algorithm does not recognise it.
- More then 20 fake dependencies required to help scheduling.

iModule: Types

```
module BinIntTrees
   flatten :: Tree → [Int]
   sum :: Tree → Int
where
   data Tree = Bin Tree Tree
             | Leaf Int
   flatten (Leaf i) = [i]
   flatten (Bin l r) = flatten l ++ flatten r
   ...
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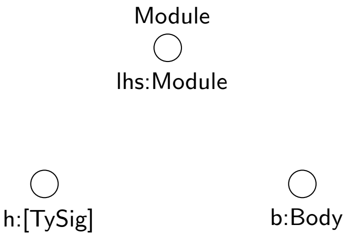

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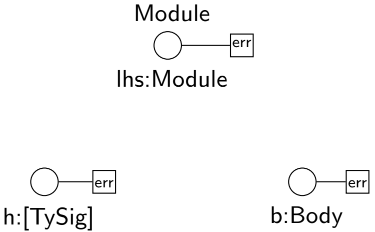

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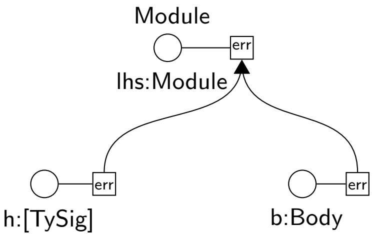

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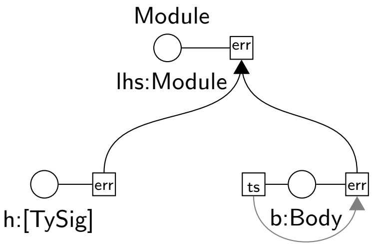

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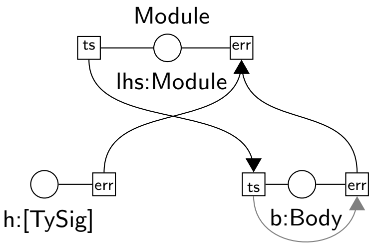

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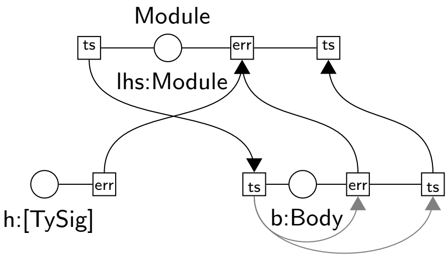

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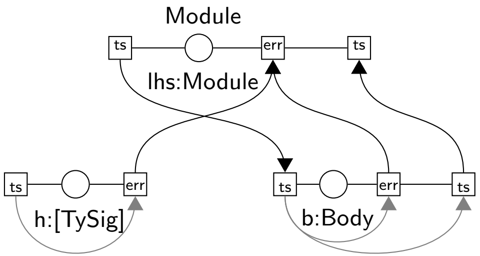

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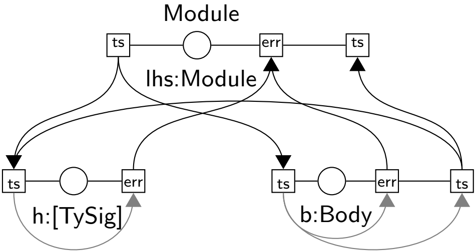

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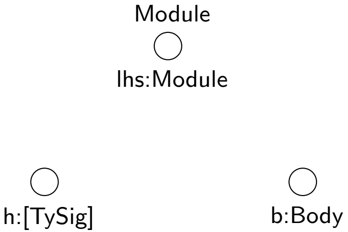

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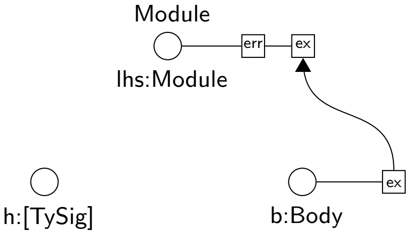

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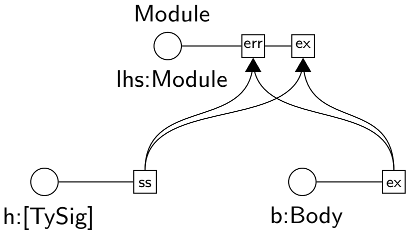

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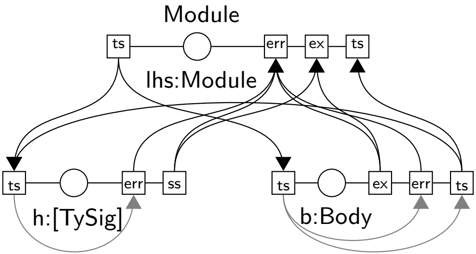

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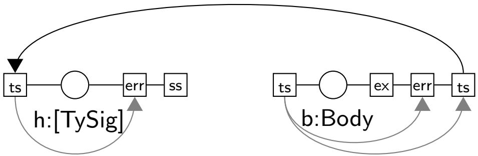

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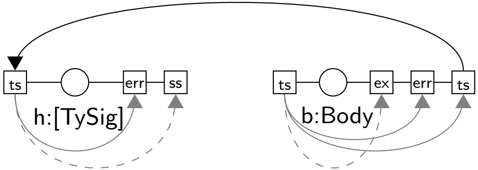

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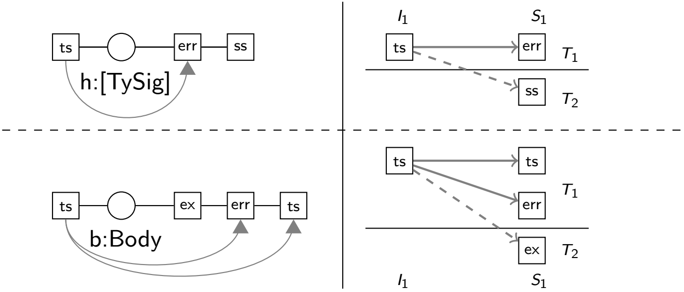
Kastens Algorithm



"Say $a \rightarrow b$ if a is at the i'th and b at the $(i-1)$'th position in the partial order implied by the dependencies."

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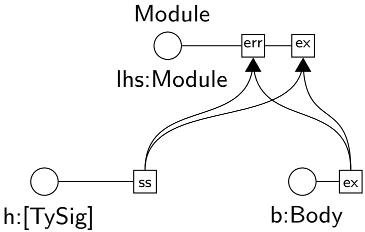

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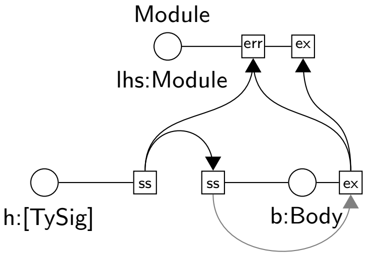

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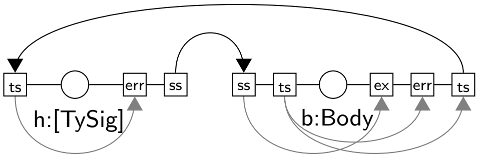

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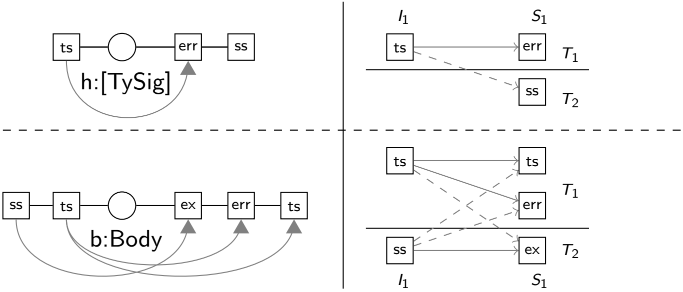

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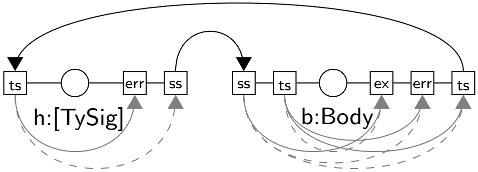

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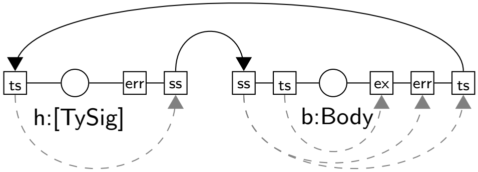

Approach

1. Make all missing assignments optimistically.
2. When a cycle without optimistic assignments is encountered: AG $\notin$ LOAG.
3. When a cycle c with optimistic assignments is encountered:
   3.1 Select an optimistic assignment, swap it and recurse (goto 1).
      - The assignment is not considered optimistic anymore.
      - If AG $\notin$ LOAG is returned: swap other assignment and recurse.
      - If no more optimistic assignments in c: AG $\notin$ LOAG.
      - Otherwise: AG $\in$ LOAG.
4. AG $\in$ LOAG.

Results

- We can now compile the UHC without fake dependencies.
- In comparable time, 25 sec vs 35 sec.
- 10 corrections and no backtracking required!
- Most time is spent propagation dependencies.

Conclusions and Contributions

- We have given a decision procedure for the class of LOAGs.
- Exponential algorithm in theory, efficient in practice.
- Backtracking should be rare.

Future Work

LOAG algorithm

- We built a fast LOAG algorithm using SAT-solving (< 10 sec).
- We wish to show it can be optimised for specific needs.
- Perhaps the approach can be generalised for other problems.

Code efficiency

- Formalise the costs of schedules by fixing an execution model.
- Possibly by developing a specialised virtual machine for AGs.
- Compare existing algorithms and the schedules they produce.
- Extend the algorithm(s) with user defined optimisations.

Attribute Grammars

Why AGs are used

- AGs form a DSL for tree-based computations.
  - Semantics.
  - Static analyses.
- Declarative programming in imperative settings.
- High level of abstraction and concern separation.
- UUAGC generates the boilerplate code we need.

Why AGs aren't used

- Generated code is often not optimal.
- Finding a static evaluation order is hard:
  - Scheduling UHC requires manual assistance.

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Questions

How fast discovers the algorithm that an AG $\notin$ LOAG?

- Very fast for Circular AGs.
- Problematic on Absolutely Non-Circular AGs (time ???).

Questions

Why is LOAG preferred over ANCAG?

- Static schedules. (simple evaluators, optimisations)
- Context-free evaluation.

To program with AGs is

1. Specifying the Abstract Syntax Tree.
2. Add attributes to nonterminals.
3. Specifying the 'arrows'.

AG Syntax

data Module | Module *h* : [**TySig**] *b* : **Body**
...
attr Module
  syn *err* : `Bool`
  ...
sem Module | Module
    $lhs.err = @b.err \lor @h.err$

Design Choices

- Which AG compiler to use?
- Which host language to use?
- Which code generation procedure to use?
- Which (data)types to use for the attributes?
- How to compute all attributes with incoming arrows?

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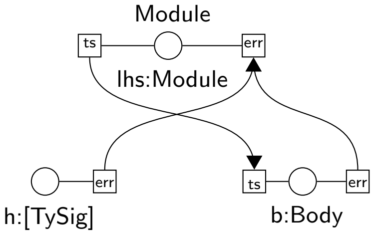
Using the UUAGC

- Copy rules generate ‘logistics’.
- Use rules combine 0,1,2,. . . attributes.



- Local attributes act like new terminals.
- Higher-order attributes act like new nonterminals.

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Code Generation Procedures

- Circular AGs: Relying on Haskell's laziness.
- Absolutely Non-Circular AGs: Kennedy-Warren algorithm.
- Ordered AGs: Kastens algorithm.

Code Generation Procedures

- Circular AGs: Relying on Haskell's laziness.
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- Linear Ordered AGs.
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